

REVIEWS.

ART. XVII.—*Claude Bernard and his Physiological Works.*

CLAUDE BERNARD was born on the twelfth of July, 1813, and died on the tenth of February, 1878, in the sixty-fifth year of his age. About the year 1834, a young man hardly twenty-one years of age, he entered Paris, bringing with him a tragedy. In his native village, Saint-Julien, near Villefranche (Rhône), he had studied pharmacy. Aspiring to fame in the world of letters, he had written a *vaudeville* which had been played at Lyons. Dissuaded by Saint-Marc Girardin from the course which he had marked out for himself, he entered upon the study of medicine soon after his arrival at Paris. In 1839 he was admitted an *interne*, having been successful in the *concours*, into one of the hospitals of Paris. The practical work of his profession, however, failed to satisfy the full measure of his aspirations, and he did not find in it the vocation to which he was destined. Although he published, in conjunction with Huette, a superb work upon *Operative Medicine*, which was translated into English, German, Dutch, Italian, and Spanish, his success as a writer upon surgery has been so far overshadowed by his brilliant achievements in physiology, that this work, upon which another might have built an enduring reputation, is now regarded merely as an episode in his remarkable career. If what is called genius ever belongs to men of science, Claude Bernard was a man of genius. In the chair of medicine in the *College of France*, he was the immediate successor of Magendie, and he occupied a professorship that had been filled by Vidius, Sylvius, Riolan, Corvisart, and Laennec. His successor may bear comparison with any of his predecessors more easily than with Claude Bernard.

A complete account of the labours of Bernard since he first entered the field of what may be termed experimental physiology would be the greatest part of a history of the progress of physiology for the past thirty-five years. The influence of his method is now felt wherever physiology is studied. Investigators in all parts of the civilized world are now treading in the paths opened by Bernard. His younger disciples may live to see the day when all but Frenchmen will forget that Bernard was born in France, and will remember only that his name and fame belong to Physiology.

The first important physiological memoir published by Bernard was entitled *Recherches anatomiques et physiologiques sur la corde du tympan*, 1843. Bellingeri, in 1818, discussed the question as to whether the sense of taste in the tongue was derived from the proper filaments of the fifth nerve, or from the facial by the chorda tympani. In 1821 Roux described loss of taste on one side of the tongue attending paralysis of the facial. In 1831 Montault described the same condition in certain cases of facial palsy. Notwithstanding these observations, however, the general opinion was that the lingual branch of the fifth was a nerve of taste, and this was described in works upon anatomy and physiology as the gustatory branch

of the fifth. Bernard gave a minute description of the course and relations of the chorda tympani in different classes of animals and in man. He showed, by direct experiments upon animals, that destruction of this nerve had no effect upon the general sensibility of the tongue, but that it affected the sense of taste alone. In a second memoir, published in 1845, he confirmed the results of his experiments upon the inferior animals by observations upon the human subject. Bernard established the definite scientific fact that the chorda tympani presides over the sense of taste in the anterior portion of the tongue. As such it remains and is accepted at the present day by nearly all physiologists.

In 1844 Bernard published an article on the gastric juice, in which he recited a number of ingenious experiments with regard to the elimination by the gastric mucous membrane of certain foreign substances introduced into the circulation. He caused an animal to swallow a salt of iron, and then injected a solution of ferrocyanide of potassium into the veins. He noted, after a short interval, the formation of Prussian blue in the stomach, showing that the ferrocyanide had passed into the gastric juice. He made at the same time other experiments, injecting cane-sugar, gelatine, and albumen into the bloodvessels; but these experiments were not so important as those which he made later, in conjunction with Barreswil, upon the nature of the free acid of the gastric juice, showing, in the first place, that a certain degree of acidity of the gastric juice was necessary to its digestive power, the nature of the acid being not absolutely essential. In 1844 he published another memoir, showing the arrest of stomach digestion by section of the pneumogastric nerves. It will be remembered that our accurate knowledge of stomach-digestion dates from the experiments upon Alexis St. Martin, published by an American physician, Dr. Beaumont, in 1833, and that the observations by Bernard were made immediately after the experiments published by Blondlot in 1843, when very little was known of the physiological action of the stomach. Aside from one of the most important discoveries made by Bernard, viz., the action of the pancreatic juice in digestion, he made, very early in his career, important observations upon the mixed digestive fluids found in the small intestine, and he showed their action upon various alimentary substances, including the albuminoids.

In 1848 Bernard made a discovery which attracted more attention than any new development in physiological science since the discovery of the distinct properties of the anterior and posterior roots of the spinal nerves. In that year he published, in the *Archives générales de médecine*, a memoir entitled *De l'origine du sucre dans l'économie animale*. This publication, which afterward appeared *in extenso* in the *Comptes Rendus de l'Académie des Sciences* in 1850, and which received the prize of experimental physiology in 1857, made a most extended and profound impression. The observations therein detailed were soon repeated in France, Germany, England, and America, and Bernard became recognized at once as one of the greatest of living physiologists.

It is difficult to imagine a discovery so extended in its applications, and so complex as this has proved to be in its relations, which could have been more thoroughly elaborated by its author. In the first place, the method of its development is a perfect illustration of the system of investigation which dates in physiology from the discovery of the circulation of the blood by Harvey, and which is so strongly set forth as the only reliable system of scientific research by Bacon. Followed, as it was, by numerous other

important discoveries by Bernard, it is not to be wondered at that enthusiastic workers sprang into existence wherever physiology was studied, followers of what began to be known as the French school. It will not be difficult for many who read this notice to remember the deep impression made upon medical men not specially interested in pure physiology by the researches of Bernard. He was visited by nearly all physicians who went from this country to Europe to study disease in the hospitals. We now have in our mind the remembrance of accounts given us by old practitioners of medicine, of the wonderful dexterity in experimentation, the unvarying affability, and the patient and kind attention always given to strangers by the great French physiologist. In ingenuity in devising new methods of verifying and enforcing his doctrines, and in skill in their execution, no one has ever equalled Claude Bernard. A practical physiologist, whose studies began at the time when he was at the zenith of his renown, could hardly write a notice of his works that would appear to be less than a eulogy. He passed away as he lived; and he corrected the proofs of an unfinished publication upon his death bed.

The story of the discovery of the glycogenic function of the liver is a most interesting illustration of the method of study which Bernard followed out with such remarkable success. In 1848, having reflected that sugar was sometimes discharged in the urine in disease, he conceived the idea that there must be some organ in the body designed to consume and destroy it as sugar, in health. His first experiments were undertaken with the view of discovering this organ and its functions. With this object in his mind, he fed a dog with a mixture containing large quantities of starch and sugar, and attempted to follow the sugar as it passed in the blood through the various organs. He analyzed the blood of the portal vein, and found sugar. He then examined the substance of the liver and the blood of the hepatic veins, still finding sugar. As a counter-experiment, he examined the blood and the substance of the liver in a dog that had been fed exclusively upon meat. He found no sugar in the portal vein, but it existed in abundance in the liver and in the blood of the hepatic veins. This was the discovery of animal glycogenesis. Unlike most great discoveries, no one had prepared the way, and the discovery was made unexpectedly at the very threshold of the experimental investigation.

The perfection of detail to which the discovery of animal glycogenesis was brought by its author is almost without a parallel in the history of physiology. Harvey left to Malpighi the task of discovering the system of vessels connecting the arteries with the veins; but Bernard left scarcely anything for his contemporaries or his successors but to verify his results. In his memoir published in 1850, he showed that glycogenesis exists in man, in the quadrumana, the carnivora, rodentia, ruminantia, and the pachydermata, as well as in birds, fishes, reptiles, mollusks, and articulate. He has since answered, and, indeed, he answered to a great extent in advance, all the objections that could be raised against his conclusions. In successive publications, he showed the mechanism of the production of sugar by the liver, an amyloid substance, which he called glycogenic matter, being formed first, this substance being gradually converted into sugar, and as sugar being taken up by the blood of the hepatic veins. The experiment by which this was demonstrated was the following: A liver taken from an animal just killed was washed free from sugar by a stream of water passing through the bloodvessels. From such a liver the glycogenic matter may be extracted, or, if the liver be kept in a warm place for a number of hours, sugar will make

its appearance in its substance by the change of a portion of its glycogenic matter. In the course of his investigations upon this subject, he showed the influence of digestion, inanition, and various other conditions upon glycogenesis. He divided the pneumogastric nerves, and arrested the production of sugar; he stimulated the same nerves, and exaggerated its production so as to render an animal diabetic. He irritated the floor of the fourth ventricle, and produced artificial diabetes (1849). He showed the reflex action of irritation of the filaments of the pneumogastriacs distributed to the lungs. He discovered the glycogenic function of the placenta, which exists before this function is performed by the liver, in the fœtus. Not to follow out his observations in their order and in full detail, his experiments were so varied and numerous, and he completed the discovery so thoroughly, that the name of Claude Bernard is the only one that has any real connection with the function of glycogenesis in animals.

The next important discovery made by Bernard was in 1848, following closely upon the publication of his researches upon the glycogenic function of the liver. At that time our knowledge with regard to the function of digestion was very limited and indefinite. Writers described a process called chymification, as occurring in the stomach, the food being reduced in this organ to a pulaceous mass, and chylification in the small intestine, where the food became liquefied and was taken up in the form of chyle. Although allusions had been made to the function of the pancreas in the digestion of fats, by De Graaf, in 1671, and by Eberle, in 1838, nothing definite was known of the action of the normal pancreatic juice before the announcement of the discovery of its true function by Bernard to the Society of Biology of Paris, in 1848, the experiments dating from 1846.¹ In completeness of detail and in perfection of logical deduction from full and definite experimental results, the history of the function of the pancreas as given by Bernard is fully equal to his description of animal glycogenesis. Before the publication of his memoir, the pancreas had been called the abdominal salivary gland, and it was supposed by some to moderate the acidity of the bile, an idea so indefinite that it hardly merits the name of an hypothesis.

Bernard was the first physiologist who obtained pure, normal pancreatic juice from a fistula in a living animal. He demonstrated its reaction, its general properties, and its action in digestion, not only upon fats but upon other alimentary matters. In his first publication he answered various objections which were subsequently made, showing that the fluid discharged from a permanent fistula, or from a fistula of several days' standing, was abnormal. He showed that the normal pancreatic juice was the only one of the digestive fluids that would instantly form a complete and permanent emulsion with fats. This fact he demonstrated in various classes of animals. He also showed that fatty matters passed through the intestinal canal undigested in cases of serious organic disease of the pancreas. Fatty diarrhœa coexistent with organic disease of the pancreas had been observed by Dr. Richard Bright in 1832, but this did not serve to direct the attention of physiologists to the action of the pancreatic juice in digestion. Bernard noted the fact that, in the rabbit, the opening of the pancreatic duct is several inches below the orifice of the bile-duct. He showed by experi-

¹ We have mentioned the glycogenic function of the liver first, as it was the publication of this discovery which seems to have produced the more decided impression. The discovery of the action of the pancreas in the digestion of fats was published at about the same time.

ment that lacteals filled with white chyle first appeared in this animal below the opening of the pancreatic duct.

In 1859 Bernard published a second series of experiments, in which he showed the effects of destruction of the pancreas in living animals. Animals in which the pancreas had been destroyed by the injection of melted tallow into the ducts died of inanition, although the appetite was voracious and large quantities of food were taken, showing that the function of the pancreas was essential to life. In these animals fatty matters passed through the intestinal canal undigested, and the digestion of meats, also, was incomplete. In addition to the function of the pancreatic juice in the digestion of fats, Bernard demonstrated its action upon albuminoid articles of food and upon cane-sugar, showing that it is probably the most important of the digestive fluids, and the one possessing the most varied properties and functions. His description of the functions of the pancreas left little to be learned. It was, like most of his systematic series of investigations, complete in itself.

Another very important discovery made by Bernard early in his career as a physiologist was that of the functions of the spinal accessory nerve in connection with phonation. This was published first in 1844, thus antedating the publication of his observations upon glycogenesis and upon the functions of the pancreas, both of which appeared in 1848. As we progress in our account of the physiological labors of Bernard, we find it difficult to carry out an analysis, even of his most important works alone, in a strictly chronological order. He made important researches in connection with nearly every subdivision of the subject of physiology, and, particularly in the earlier part of his career, his experimental labours were enormous and exceedingly varied. Most of those who are at all familiar with physiological literature at once connect the name of Bernard with the discovery of the sugar-producing function of the liver, and it is only natural to give prominence, early in this notice, to his experiments upon this subject; but a more connected history of his other contributions to physiological knowledge can be given, if we classify his researches, as far as possible, according to the systems to which they relate.

Bernard's contributions to our knowledge of the functions of the digestive system were many and varied. We have already alluded to his experiments upon the gastric juice and stomach-digestion. He was one of the first to recognize the importance of studying the combined as well as the successive action of the different digestive fluids, introducing a truly philosophic method into the study of their functions. Among the earliest of his works is a series of observations upon the properties and functions of the saliva.

In 1831 Leuchs discovered the action of the mixed saliva in changing starch into sugar. In 1845 a commission, consisting of Magendie, Rayer, Payen, and others, made an interesting report to the Academy of Sciences of Paris upon the mixed saliva of the horse; but they obtained the fluid by causing a horse to eat bran that had been carefully washed, taking the mass, as it was swallowed, from an opening in the œsophagus, and separating the saliva. In 1847 Bernard, taking up the question where it had been left by the commission, carefully studied the properties of the pure secretions taken from the ducts of each of the three salivary glands, the properties of these three fluids mixed, and the properties of the mixed saliva and the mucus of the mouth and pharynx. Physiologists now have a very distinct idea of the time of secretion and the properties of each

of the three varieties of saliva, and their connection with mastication, gustation, deglutition, the digestion of starch, and the process of stomach-digestion. It is not too much to say that these definite notions depend mainly upon the experiments made by Bernard since 1847.

In 1850 Bernard made a series of interesting experiments upon the influence of the pneumogastric nerves upon the œsophagus. He showed that deglutition was impossible immediately after section of these nerves in the neck, that the food which passed below the pharynx remained in the œsophagus and did not reach the stomach, and that the so-called vomiting, which sometimes occurs, is due to contraction of the muscular structure of the œsophagus, when its fibres are directly excited to action by distension of the tube.

In the summer of 1855 the lectures delivered by Bernard at the College of France were devoted to the subject of digestion. They were published in 1856, under the following title: *Leçons de physiologie expérimentale appliquée à la médecine; tome deuxième. Cours du semestre d'été 1855.* These lectures contained a full and extended account of all of his discoveries which relate to digestion, as well as historical *résumés*. He gave, also, a most intelligent and appreciative summary of the observations of Dr. Beaumont upon Alexis St. Martin. Later researches have corrected but few errors in these lectures delivered by Bernard in 1855. His first published lectures, delivered in the winter of 1854-55, were devoted to glyco-genesis. The lectures upon digestion were the first which embraced a large subject, in which a consideration of the labours of others was necessarily involved. In fecundity of device for illustration, and in directness and felicity of diction, there was nothing at that time superior to them in any language. These lectures, which were read extensively in this country, had an influence beyond the mere dissemination of the discoveries made by their author. A teacher of physiology, reading these lectures, could see at once, not only a definite and striking account in words of the actual state of knowledge of the function of digestion, but he could picture to himself the vivid manner in which the subject-matter must have been enforced upon pupils by the brilliant experiments upon living animals with which they were illustrated.

In addition to the discoveries already mentioned, a very important and suggestive communication was made by Bernard to the French Academy of Sciences, in March, 1846. In this, Bernard presented the results of a series of experiments upon herbivorous and carnivorous animals subjected to an identical diet, and a comparison of the urine of the same animals deprived of food. He found that fatty matters appeared in the chyle of rabbits very low down in the intestine, and he states that this observation led him to the discovery of the organ which digested fats. With regard to the effects of deprivation of food upon herbivora, he showed that these animals, without food, became true carnivora, inasmuch as they then consumed the elements of the blood. Under these conditions the urine of the herbivora, which is normally alkaline, turbid, and rich in carbonates, became clear, acid, and rich in phosphates and urea.

In 1850 Bernard presented another important memoir to the Academy of Sciences. By a series of most ingenious experiments, he showed that cane-sugar and the albumen of white of egg must pass through the liver before complete assimilation by the blood. When these substances were injected into the jugular vein, they did not become assimilated, but were discharged in the urine. No such discharge took place, however, when

they were injected into the portal vein. He showed, also, that it was not necessary for fats to pass through the liver, and that they were absorbed by the lacteals and became directly assimilated by the blood. As the result of these experiments, he concluded that the chyle is not to be considered as a liquid containing all of the nutritive principles resulting from digestion, as had been the almost universally adopted opinion.

The two volumes of lectures published by Bernard in 1859, entitled *Leçons sur les propriétés physiologiques et les altérations pathologiques des liquides de l'organisme*, appeared just after his lectures upon the nervous system, which latter will be referred to in another connection. These lectures were even more exhaustive and elaborate than those upon digestion. The first volume was devoted to a consideration of the blood. In 1853 he had published a memoir on the capacity of the blood of different parts for absorbing oxygen, containing a number of striking experiments. In the volume of lectures referred to, he recited a large number of exact observations upon the temperature of the blood of different parts, settling many important questions that had before been undetermined. His general conclusions from these experiments was that the seat of calorification of the blood was in all the tissues of the organism, a deduction which has been fully confirmed by subsequent observations. He then investigated the differences in the blood-pressure in different vessels, and the modifications in the pressure under various physiological conditions, the influence of the nervous system, etc. An important series of investigations made in this connection was with regard to the influence of the nervous system upon the colour of the blood, particularly the blood coming from the glands during their functional activity and during repose. His observations upon the colour of the blood coming from the salivary glands, and his description of the nervous influence over the activity of glands, were most striking, and attracted a great deal of attention. For example, he excited secretion in the submaxillary gland by stimulating what he called its motor nerve, and the venous blood from the gland became red. By stimulating another nerve he arrested the secretion, and the blood from the gland became dark.

The most important experiments, however, made upon the blood were those in which he determined the proportions of oxygen by the method of displacement with carbonic oxide. The older observations of Magnus and others had been very contradictory and obscure in their results. Bernard showed that all the methods of analysis of the blood for gases which involved a delay of several hours before the results could be ascertained were faulty, for the reason that oxygen was consumed and carbonic acid produced in the blood after it had been drawn from the body. He ascertained that, by agitating the blood with carbonic oxide, this post-mortem consumption of the oxygen is arrested; and he obtained, by using carbonic oxide to displace the oxygen, the actual quantity of this gas contained in the blood at the time that the analysis was begun. These were the first experiments which gave an accurate estimate of the actual proportion of the gases existing in the blood under different physiological conditions. They also showed the mechanism of poisoning by carbonic oxide, and illustrated the function of the blood-corpuscles as oxygen-carriers. The importance of these facts is sufficiently evident.

In the second volume of lectures upon the liquids of the organism, Bernard very clearly and distinctly defined the differences between secretions and excretions, general distinctions which have hardly met with the atten-

tion at the hands of writers upon physiology that their importance and accuracy merited. I pass over the reiteration of his views upon the properties and functions of the digestive fluids, which were enforced by additional experiments, and come to his researches upon the mechanism of secretion and excretion.

In 1821 Prévost and Dumas, who demonstrated the accumulation of urea in the blood following extirpation of the kidneys, gave to practical physicians the first definite and positive basis for a rational pathology of renal diseases. These experiments were confirmed and somewhat extended by other observers before the time of Bernard. The important fact developed by the researches of Prévost and Dumas was a great discovery; but Bernard, bringing to a study of the question his matchless ingenuity and dexterity in experimentation, filled many of the gaps left in the original investigations. He showed the vicarious elimination, for a time, of urea by the stomach and intestines, during which time there is no accumulation of urea in the blood, following extirpation of the kidneys; and he demonstrated that, after the vicarious elimination of urea has ceased, this principle produces blood-poisoning. His experiments answer most completely the objections which were subsequently made to the idea that urea is formed in the system and eliminated by the kidneys, and is not formed in the kidneys, by Oppler, Perls, Zalesky, and others. In short, Bernard settled beyond a reasonable doubt the doctrine that all the excrementitious principles are formed in the system at large by the process of disassimilation, and are eliminated by proper organs.

We do not remember that any physiologist, before Bernard, enunciated definitely and positively the great distinctions between secretions and excretions, which he states in substance as follows: First, that the production of secretions is generally intermittent, while the production of excretions is generally constant; second, that the elements of the true secretions do not pre-exist in the blood, but are formed *de novo* in the glands themselves, while the elements of excretion pre-exist in the blood, and are not formed in excreting organs; third, that removal of secreting glands does not cause an accumulation of the elements of secretion in the blood, while removal of excreting organs is followed by accumulation of excrementitious matters in the blood after their removal by vicarious action is arrested; and, finally, that secretions have important functions to perform in the economy, while excretions have no function to perform and are simply separated from the blood to be discharged from the body.

In the same volume Bernard took up again the question of the influence of special nerves over the salivary secretions. He extended his observations by a variety of most delicate and ingenious experiments, showing the influence of certain nerves, not only over secretion but upon the blood-pressure, the colour of the venous blood coming from the glands, and the proportion of oxygen in the venous blood during glandular repose and activity. He demonstrated the general law that, during the so-called repose of true secreting organs, the cells of the glands are forming the characteristic elements of the secretions; that when the secretion is discharged, the supply of blood sent to the glands is largely increased, and the elements of the secretions are washed out, so to speak, by a watery transudation and are discharged by the ducts. This law gave physiologists an idea of the reason why the flow of true secretions cannot be constant, a certain period of so-called repose being necessary for the formation of the proper elements of secretion. It explained the fact that the fluid discharged without inter-

mission from a permanent pancreatic fistula is not normal and does not possess the digestive properties of the true pancreatic juice, for the reason that no interval exists for the formation of pancreatine by the cells of the gland. This completely answers the objections made by certain physiologists to the conclusions drawn from Bernard's original observations upon the pancreas.

In 1857 Bernard published a course of lectures entitled *Leçons sur les effets des substances toxiques et médicamenteuses*. These lectures were delivered at the College of France in 1856, just after the death of Magendie, his illustrious predecessor in the chair of medicine. The first lecture of this course was an admirable review of the life and labours of Magendie. Bernard had been his prosecutor and assistant for many years; he had supplied his place in the lecture-room; but Magendie, the greatest physiologist of his day, the discoverer of the properties of the roots of the spinal nerves, has the honour, almost as great as any achieved by his own labours, of having been the master of Claude Bernard. Bernard's eulogy of Magendie was a modest and touching tribute of one great man to another who had been his guide and model.

In his lectures upon toxic and medicinal substances, Bernard developed many new ideas with regard to the action of deleterious and irrespirable gases, and showed the true mechanism of death from inhalation of carbonic acid. He also made a number of interesting experiments, entirely novel in their character, upon the tolerance of a vitiated atmosphere by animals slowly and gradually subjected to its action. In these experiments, he studied the action of carbonic oxide in fixing itself in the blood-corpuscles, and rendering them incapable of absorbing oxygen and carrying it to the tissues. But one of the most important of his series of observations related to the effects of the woorara poison—called by the French *curare*. He was one of the first, if not the first, to thoroughly investigate this remarkable agent, which is now so largely used in physiological investigation, showing its peculiar effects upon the motor system of nerves. It was by experiments with woorara that Bernard was able to settle definitively the fact of the mutual independence of muscular and nervous irritability.

Many of the most important discoveries made by Bernard relate to the physiology of the nervous system. We have already alluded to his researches on the functions of the chorda tympani nerve, published in 1843, from which his brilliant career as a physiologist may be dated. We remember well a conversation with Bernard in 1861, in which he referred to this memoir. His young friends, *internes* in the Paris hospitals, finding him at work, asked what he was doing. When told that he was writing a memoir on the chorda tympani, they showed some surprise and amusement that he should write a lengthy paper on such a little nerve. Bernard related with much humour this little incident, and his memoir showed that the small nerve was not without great physiological interest and importance. Bernard did few small things. He was one of the rare investigators of our time who had little to do with trivialities. In a social and amiable way, he often referred to a class of physiologists who contribute to literature a mass of little things, unimportant in themselves and in their relations, and simply showing work. "Some men," he said, "will publish minute details of a hundred experiments, ninety-nine of which are failures, and they seem to think that it is sufficient to do work, although they may really accomplish little or nothing." We know of no experiments published by Bernard that are not intelligent, useful, and

important. He was not fond of complicated and intricate apparatus; and he made his investigations in the simplest way, so that most of his experiments could be easily repeated by a practical observer. His results are an illustration of the fact that an imposing laboratory and complex machinery for investigation do not of necessity make the greatest physiologists or lead to the most important discoveries.

One of the most remarkable errors made by Bernard in his earlier writings upon the nervous system was that he ascribed the discovery of the distinct properties of the roots of the spinal nerves to Sir Charles Bell, and characterized the observations of Magendie as simply confirmatory. His two volumes of *Lectures on the Nervous System*, published in 1858, embody his views and discoveries up to the date of publication. In the first volume he says: "Charles Bell had indicated by induction, about the beginning of this century, that the posterior roots should be sensitive and the anterior roots motor. We know that later Magendie found, by dividing separately one and the other, that, upon this point, the views of Charles Bell were exact." It was not until 1867, ten years later, in his report on the progress of physiology in France, that he rendered full justice to Magendie, who was the real discoverer of the properties of the roots of the spinal nerves in 1822. In this report Bernard says: "In 1811, then, Charles Bell did not know the functions of the roots of the spinal nerves; he falsely interpreted a fact which it has been desired later to allege in his favour."

It is certain that Bernard did not intend or desire to deprive Magendie of the credit of any discovery; and it must be remembered that Sir Charles Bell's pamphlet, entitled *An Idea of a New Anatomy of the Brain*, was not accessible, and was known only through extracts and an obscure republication which appeared anonymously in 1839. During a certain period of his physiological career, Bernard was more occupied in making than in studying physiological literature, and he had little or no knowledge of the English language. Nearly all of his works, particularly those of early date, were full of original research and contained little in the way of historical discussion. His later writings, however, showed more of a tendency to generalization; but he still dealt largely with facts that he had developed by his own researches.

Those who are interested in the history of what is termed nerve-physiology, which is so much studied at the present day, will find, in the first volume of Bernard's lectures on the nervous system, published in 1858, most elaborate and interesting researches on the phenomena developed by the application of galvanic currents to the nerves. In this volume he also made some important additions to our knowledge of reflex action.

The second volume of the lectures on the nervous system, published in 1858, embodies nearly all of Bernard's discoveries with regard to the functions of special nerves. The same ingenuity in devising experiments to settle disputed questions and develop new facts is observed in this as in his other writings. He devised a method of cutting the facial in the case of the tympanum, and noted the effects upon animals of intracranial and extracranial section of this nerve. He took up Magendie's operation of intracranial division of the large root of the fifth nerve, and studied most accurately the effects of its section before and after it had received its communicating filaments from the sympathetic. He made a number of most interesting experiments, also, upon the motor nerves of the eye, and showed the influence of the third nerve upon the movements of the iris.

We have already briefly referred to the memoir upon the functions of the spinal accessory nerve, originally published in 1844. In 1832 Bischoff published a series of experiments upon goats, in one of which, having divided all the roots of the spinal accessory on both sides, with extensive exposure of the parts which greatly exhausted the animal, he found that the sound emitted by the larynx "was one which could in no wise be called voice." This experiment, however, was very unsatisfactory, and attracted but little attention. Before the publication of Bernard's memoir, it was generally held by physiologists that the recurrent laryngeal branches of the pneumogastrics were the nerves of phonation.

One of the greatest merits of Bernard's observations upon the spinal accessory was the method which he employed for extirpation of the nerve. The difficulty had been, in the experiments of Bischoff, to divide all of the roots without such a shock to the animal and excessive loss of blood as to render very unsatisfactory any observations after the section had been made. It will be remembered that the extensive origin of the nerves from the medulla oblongata and the cervical portion of the spinal cord had apparently rendered it necessary to open a large portion of the spinal canal. Bernard attempted to do this after Bischoff's method, but without satisfactory results. He then devised the method of removing the nerve by avulsion. He cut down upon the muscular branch as it passes through the sterno-cleido-mastoid muscle, followed up the nerve by careful dissection as far as the posterior foramen lacerum, seized the trunk as it emerges from the foramen with broad-billed forceps, including the communicating branch to the pneumogastric, and then, by gentle, firm, and steady traction, he pulled out the entire nerve by the roots. These experiments he performed upon young cats, dogs, and guinea-pigs. When both nerves were completely extirpated in this way, the voice was abolished, while the respiratory movements of the larynx were not affected. Extirpation of one nerve rendered the voice hoarse. Extending his experiments still further, he showed that the filaments which preside over the vocal movements of the larynx come from the roots originating at the medulla oblongata, and that the roots from the spinal cord send their filaments to the muscular branch. By these most simple and satisfactory experiments, it was definitely ascertained that the innervation of the larynx is double; that the nerve which animates the muscles concerned in modifying the tension of the vocal cords is the spinal accessory, the filaments of which go to the pneumogastric by the communicating branch and pass to the larynx through the recurrent laryngeals; and that the filaments of the recurrent laryngeals which preside over the ordinary respiratory movements of the larynx are derived from other motor communications of the pneumogastric, and not from the spinal accessory.

In the same volume of lectures, Bernard recites a number of interesting and original experiments upon the pneumogastric nerves and their various branches.

We now come to a discovery with regard to the nervous system which has, perhaps, been more extended by subsequent observations than any other that we have mentioned. We refer to Bernard's observations upon the nerves of the so-called sympathetic system.

In 1816 Dupuy removed the superior cervical sympathetic ganglion in horses, and noted vascular injection of the conjunctiva, increase of temperature in the ear, and an abundant secretion of sweat upon the side of the head and neck corresponding to the section. In the *Comptes Rendus de la*

Société de Biologie, Paris, 1851, tome iii, page 163, Bernard reported a series of experiments upon rabbits, in which he divided the sympathetic in the neck upon one side, and noted, on the corresponding side of the head and the ear, increased vascularity, and an elevation in temperature, amounting to from 7° to 11° Fahr. This condition of increased heat and vascularity was sometimes observed for several months after division of the nerve. Brown-Séquard repeated and extended these observations very soon after; but we cannot find that his experiments were published before they appeared in *The Medical Examiner*, Philadelphia, August, 1852. The experiments of Dupuy attracted very little attention. Valentin made a reference to filaments of the sympathetic distributed to the blood-vessels and influencing their calibre, in 1839. We regard Bernard as the discoverer of the vaso-motor system of nerves; and it is certain that the publication of his experiments antedated the appearance of Brown-Séquard's observations by about one year. We hardly need discuss the great importance of this discovery, showing, as it does, the influence of the sympathetic upon the supply of blood to parts, calorification, and nutrition, nor shall we refer in detail to the facts that have been developed by others as a consequence of the experiments of Bernard. The observations published in 1851 were the real starting-point of our present knowledge of the functions of the sympathetic system.

The two volumes of lectures on the *Liquids of the Organism* were published in 1859. From that time until 1865, when a volume of lectures appeared, entitled *Introduction à l'étude de la médecine expérimentale*, the literary labours of Bernard were confined mainly to articles in the *Journal de la physiologie*, the publication of which began in 1858. To this Journal, which was continued as the *Journal de l'anatomie et de la physiologie* after 1864, Bernard contributed numerous original papers. In 1863 there appeared the first number of the *Revue des cours scientifiques*, which was continued after 1871 as the *Revue scientifique*. The editors of the *Revue* published the lectures of Bernard as they were delivered, and the last appeared after his death. The most important of these lectures were afterward collected and published as separate volumes. The *Introduction à l'étude de la médecine expérimentale*, published in 1865, was followed, in 1866, by the *Leçons sur les propriétés des tissus vivants*; this, by the *Leçons de pathologie expérimentale*, published in 1872; this, by the *Leçons sur les anesthésiques et sur l'asphyxie*, published in 1875; this, by the *Leçons sur la chaleur animale*, published in 1876; this, by the *Leçons sur la diabète et la glycogénèse animale*, published in 1877; and finally, just after the death of the author (1878), two volumes have appeared, one entitled *La science expérimentale*, and the other, *Leçons sur les phénomènes de la vie*.

A full analysis of the original contributions of Bernard to physiological literature would extend itself nearly to the dimensions and scope of a systematic treatise. There are few subjects connected with physiology that do not bear the impress of his labours. His memoirs and lectures up to 1859 were mainly original, and they contained little in the way of generalities, although he prefaced nearly all of his volumes with an exposition of the experimental method. After 1865 the character of his thoughts and studies seems to have changed. While he constantly reiterated his original views and extended his observations in the directions opened by his own discoveries, he devoted more attention to generalization and to the results of the labours of others. His method, which was rigidly experi-

mental and deductive, he constantly advocated, and the labours of his pupils in France and elsewhere have borne testimony to the good effects of his precepts and example. It may not be out of place to refer here to the influence which his works have exerted upon physiology in this country. In 1851 Prof. Dalton gave a short course of lectures upon experimental physiology to the students of the Boylston Medical School in Boston. The same year (1851-1852) he gave a course at the Buffalo Medical College, illustrated by experiments upon living animals; and in 1852 he attended Bernard's lectures at the College of France. Since 1855 he has lectured upon physiology in the same way in New York, and others have followed his example. We venture to say that demonstrative teaching in physiology in this country is to be attributed to the influence of Bernard's works, to say nothing of the original investigations which have given our own observers a more than respectable position in physiological literature. The only publication, however, which has appeared here, to which Bernard's name is attached, is a little book of *Notes of M. Bernard's Lectures on the Blood*, by Walter F. Atlee, M.D., published in Philadelphia, in 1854.

The smallest of Bernard's titles to fame were the titular and other honours that were bestowed upon him in the course of his remarkable career. About 1841, before he received the degree of Doctor of Medicine, he was attached to the laboratory of Magendie as assistant and prosector. In 1843 he took his degree in Medicine. In 1853 he was admitted a Doctor of Sciences; and the chair of general physiology was created for him in the Faculty of Sciences at the Sorbonne. From 1847 to 1855 he acted as *professeur suppléant* to Magendie at the College of France, and in 1855 he succeeded Magendie as Professor of Medicine. In 1868 he was appointed Professor at the Museum of Natural History. He was elected a member of the Academy of Medicine in 1861, perpetual president of the Society of Biology in 1867, and a member of the Institute of France in 1869. In 1867 he was appointed commander in the Legion of Honour, and in 1869 Senator of France. At the time of his death he was a member of most of the learned societies of Europe.

It has been a peculiarly agreeable task for us to attempt to follow the scientific career of the great physiologist whose labours are now ended; and we have often found it difficult to restrain our enthusiasm within the limits that we had fixed, for we intended to write a simple analytical review of his most important works. We shall not compare him with his contemporaries or with the other great discoverers whose names we revere and honour. He was a simple searcher after truth; and his thirty-five years of labour in physiology have brought forth more fruit and have done more for humanity than any one now living can hope to accomplish. His disciples may feel proud that they are permitted to continue their work as followers of Claude Bernard.

Many of the writings of Bernard are published as separate memoirs, which are difficult of access, and as contributions to periodicals; but all of his discoveries and his most important reflections upon physiological subjects will be found in the following works, which are enumerated in the order of their publication:—

Leçons de physiologie expérimentale, 1855.

Leçons de physiologie expérimentale, tome deuxième, 1856.

Leçons sur les effets des substances toxiques et médicamenteuses, 1857.

Leçons sur la physiologie et la pathologie du système nerveux, 2 vols., 1858.

Leçons sur les propriétés physiologiques et les altérations pathologiques des liquides de l'organisme, 2 vols., 1859.

Introduction à l'étude de la médecine expérimentale, 1865.

Leçons sur les propriétés des tissus vivants, 1866.

Leçons de pathologie expérimentale, 1872.

Leçons sur les anesthésiques et sur l'asphyxie, 1875.

Leçons sur la chaleur animale et sur les effets de la chaleur, 1876.

Leçons sur le diabète et la glycogénèse animale, 1877.

Leçons sur les phénomènes de la vie, 1878.

La science expérimentale, 1878.

The volume entitled *La science expérimentale* is a collection of memoirs and addresses upon different subjects connected with physiology, from 1844 to 1876. The subjects are as follows: Progrès des sciences physiologiques; Problèmes de la physiologie générale; La vie, les théories anciennes et la science moderne; La chaleur animale; La sensibilité; Le curare; Le cœur; Le cerveau; Discours de réception à l'Académie française.

A. F., Jr.

ART. XVIII.—*Higher Medical Education.*

1. *Practical Essays on Medical Education and the Medical Profession in the United States.* By DANIEL DRAKE, M.D., Cincinnati, 1832. 8vo.
2. *Lectures on Medical Education.* By SAMUEL CHEW, M.D., Philadelphia, 1864. 8vo.
3. *Contributions to the History of Medical Education and Medical Institutions in the United States of America, 1776–1876.* By N. S. DAVIS, A.M., M.D., Washington, 1877. 8vo.
4. *Higher Medical Education, the True Interest of the Public and the Profession. An Address Introductory to the 112th Course of Lectures in the Medical Department of the University of Pennsylvania.* By WILLIAM PEPPER, A.M., M.D. Philadelphia: J. B. Lippincott & Co., 1877. 8vo.
5. *De l'organisation des Facultés de Médecine en Allemagne.* Par le docteur JACCOUD, Paris, 1864. 8vo.
6. *Les hautes études pratiquées dans les Universités Allemandes.* Par ADOLPHE WURTZ, Paris, 1870. 4to.
7. *Etude sur l'organisation de la Médecine en France et à l'étranger.* Par LEON LE FORT, Paris, 1874. 8vo.
8. *Ueber das Lehren und Lernen die Medicinischen Wissenschaften an den Universitäten der Deutschen Nation.* Von Dr. TH. BILLROTH, Wien, 1876. 8vo.
9. *L'enseignement de la Médecine en Allemagne.* Par LOUIS FIAUX, Paris, 1877. 8vo.
10. *De la situation de l'enseignement Médical en France.* Par CHAUFFARD, Rev. des Deux Mondes, Jan. 1, 1878.
11. *Medical Politics; being the Essay to which was awarded the first Carmichael Prize, 1873.* By ISAAC ASHE, M.D. (etc.), Dublin, 1875. 8vo.
12. *Report of Proceedings of the Meeting of the General Medical Council in 1877.* Med. Times and Gaz., May and June, 1877.

It has been observed that the difficulty in forming an opinion on a subject is materially increased by studying it, and, as regards medical education, this statement is certainly correct. We have had occasion to examine with care the publications whose titles head this article, and have